The Promise of Regulated Deficit Irrigation in California's Orchards and Vineyards

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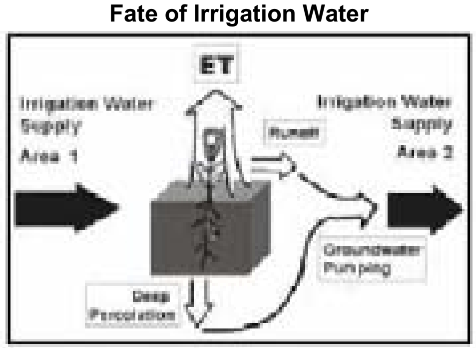
Agriculture uses about 75 percent of all the developed water in California, and the expanding population and efforts to maintain or improve animal habitat and stream flows will require even more water in the future. With no significant expansion of water supplies and possible partial loss of existing resources, agricultural water use is being seen by many as a potential water source. The recent controversy over the transfer of water from agriculture in Imperial County to the City of San Diego illustrates this issue. Some maintain that Imperial growers could free up the amount of water in question by improving their surface irrigation management, such as waste less water by reducing deep percolation below the crop root zone or end of field runoff. The growers argue that there are limits to how much water can be saved by reducing irrigation water losses (also called improving application efficiency) and point to reduced planting acreage, increased salinity, and associated loss of production and agricultural jobs as likely effects.

Figure 1
Fate of Irrigation Water



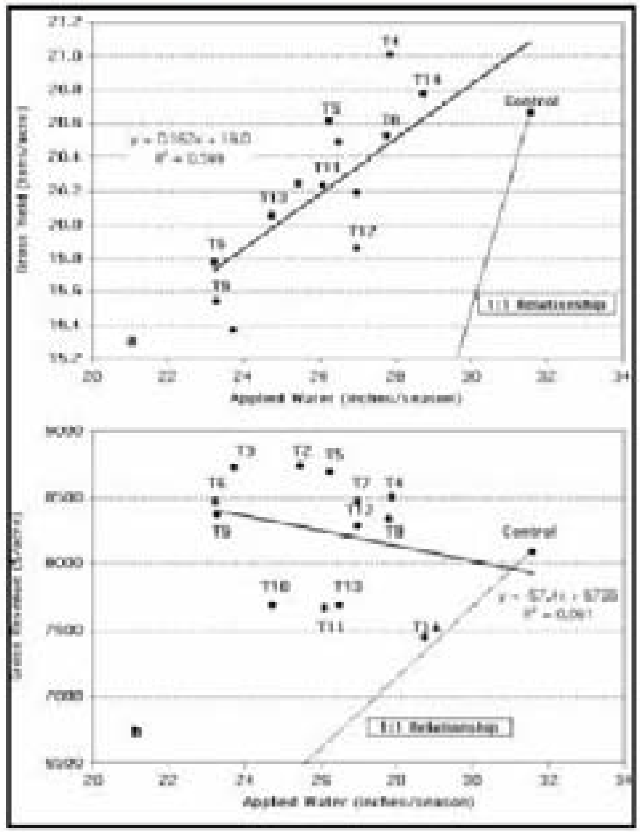
Statewide, California growers have steadily improved their application efficiency over the last couple decades. Moreover, deep percolation and runoff are usually only temporary losses on a small scale (the field being irrigated). Although quality may be degraded by fertilizers and other agricultural chemicals, water lost to deep percolation eventually moves into the water tables where it can be pumped and reused (see Figure 1). An exception to this is when it enters a salty, perched water table, usually making it unusable, or when it flows to the ocean. Runoff is often collected and reused on another field on the farm. Recognizing this and the fact that most California growers have become highly efficient in their irrigation management shows that there is limited opportunity to free up net water by improving application efficiency. Additionally, the use of California Irrigation Management Information System (see "Quantitative Irrigation Scheduling Does Work") data has allowed growers not to over-irrigate crops, minimizing the loss of water to deep percolation.

Generally a near-linear relationship exists between ET and crop production because transpiration, the movement of water vapor from the interior of the leaf to the surrounding atmosphere and the uptake of carbon dioxide, the basic building block required in the process of photosynthesis, both use the same plumbing at the leaf surface—the stomata. These are very small openings usually located on the undersides of leaves that regulate the movement of both water vapor and carbon dioxide. Indeed, it's often said that the plant trades water for carbon and if the goal is to maximize carbon uptake to achieve high yields, potential transpiration must be met. Thus, limiting transpiration (water stress) has usually been associated with production losses and lower grower profit.

While this is true for most field and row crops, it's not necessarily true for trees and vines. Lack of water (water stress) reduces the vegetative growth of plants but doesn't necessarily result in reduced fruit yield in trees and vines as it does with most field and row crops (cotton being an exception). Thus it is possible to reduce transpiration of trees and vines without reducing yield.

We have conducted RDI research on the major tree crops in California—pistachio, olive, prune, and citrus—and identified numerous species where significant amounts of water can be saved without having a negative impact on production or grower profit. We found that while the relationship between gross fruit yield (mean of three years) and applied water was fairly linear (see Figure 2a) relationship between gross revenue ($/acre) and applied water was completely different (see Figure 2b). Many of the RDI regimes had higher gross revenue than the full irrigation control while applying from 4 to 8 inches less water. This was due to significantly lower creasing (higher fruit quality), especially with early season stress. This illustrates a major difference between row/field crops and tree/vine crops.

Figure 2
Production and Revenue Functions for Applied Water Using Mean 1998 - 2000 for Navel Oranges (Frost Nucellar) in Southern San Joaquin Valley



Almond trees present the best opportunity to couple RDI with adjusted horticultural management not only to reduce water consumption but also to address two critical health issues facing the industry—agricultural burning and dust during harvest. Again working in the southern San Joaquin Valley and supported by the California Almond Board, we tested various RDI regimes ranging from water savings of 15 to almost 50 percent of potential orchard ET. We showed that mild stress over most of the season can be imposed with little negative influence on production and substantial water savings. However, a potentially more significant finding involved the RDI regimes that imposed moderate to severe preharvest (April to July) stress. These strategies reduced vegetative growth (canopy size) and individual kernel weight but had no influence on fruit load; the smaller, more compact trees had higher fruiting density (nuts per unit of canopy volume) than fully irrigated trees. Thus, one could increase the planting density (trees/acre), thereby increasing total nut production (number/acre) compared with conventionally planted and irrigated trees. The downside is that fruit size would be lower, which may somewhat decrease the value of the nuts. On the other hand, the need to prune trees would be much less, reducing the amount of pruning and burning.

Growers currently mechanically shake trees at harvest and leave the nuts on the ground to dry for 7 to 10 days before they are swept up. The sweeping and mechanical collection can create dust and related health concerns. Our research showed that preharvest stress can accelerate hull splitting, allowing for an earlier harvest, which benefits growers in a number of ways; earlier hull split allows the nuts to dry more completely on the tree prior to mechanical tree shaking. We believe that this presents the option of growers harvesting directly from the tree into nut catching machines, as is done currently in pistachio and prune orchards. This would eliminate the dust and other problems associated with nuts drying on the ground, such as ant damage and soil-borne bacteria infection.

Winegrapes is another crop where stress can substantially improve fruit quality. The irrigation of winegrapes was against the law in some European countries, such as Spain, until recently because of real or perceived negative irrigation-related impacts on wine quality. Some stress, however, is beneficial as it can reduce berry size, thereby increasing the ratio of skin to fruit volume. This is important to wine makers since the skin contains constituents important in wine color, taste, and chemical make-up.

Table 1
Range of Estimated Water Savings Relative to Current Practices Using Regulated Deficit Irrigation

Crop	Bearing Acreage (acres)	Estimated Savings (inches)	Range of Water Savings (acre-ft)
Almonds	530,000	8 to 14	424,000 to 618,000
Winegrapes	480,000	8 to 12	320,000 to 480,000
Citrus	244,000	6 to 8	122,000 to 163,000
Pistachios	78,000	10 to 12	65,000 to 78,000
Prunes	76,000	6 to 12	38,000 to 76,000
Peaches	70,000	4 to 8	23,000 to 47,000
Olives	36,000	6 to 10	18,000 to 30,000
Apples and Pears	49,000	4 to 8	16,000 to 33,000
Walnuts	196,000	Unknown	Unknown
Total	**1,759,000**	**52 to 84**	**1,026,000 to 1,525,000**

Using our research and that of others and conservative estimates of current practices in orchards and vineyards, we have calculated a range of water savings for the major tree crops and winegrapes in California. These estimates are based on RDI regimes that do not reduce grower profits. One tree crop, walnuts, is excluded since we have no data showing that RDI can be successful although further research is planned. Water savings on the low end, those that we believe are currently achievable, total about 1 million acre-feet (see Table 1). If we include RDI adoption coupled with adjusted horticultural practices, such as the higher almond density plantings and improved, more precise methods of identifying tree stress, we believe that 1.5 million acre-feet can be saved. We are currently conducting research on developing electronic sensors that can accurately detect tree stress thus allowing the management of RDI strategies with precision and without risks. Today's farming economy has resulted in the steady conversion of relatively low-value row crop land into higher profit orchards and vineyards. This process only enhances the scale of potential RDI adoption. Achieving the promise of RDI depends on growers recognizing the benefits of managed water stress. This requires demonstrating on a large scale that RDI can be successful in their terms—profits are maintained or increased—and that the higher level of irrigation management required is within the ability of on-farm personnel. We believe that RDI in orchards and vineyards could be a key component in this state's effort to meet the growing demand for water and at the same time, preserve and protect permanent crop production.